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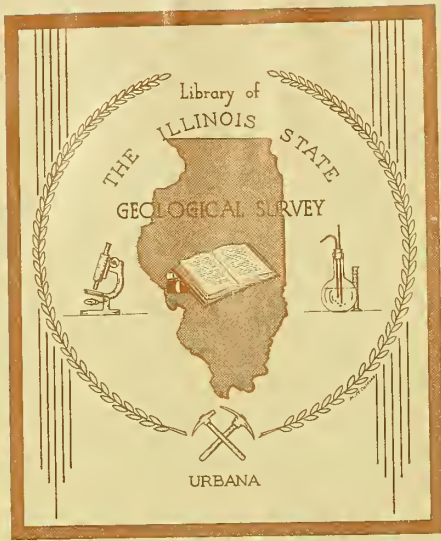
Major, Minor, and Trace Elements in
Sediments of Late Pleistocene
Lake Saline Compared with Those
in Lake Michigan Sediments

John C. Frye and Neil F. Shimp



ILLINOIS STATE GEOLOGICAL SURVEY

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MAJOR, MINOR, AND TRACE ELEMENTS IN SEDIMENTS OF LATE PLEISTOCENE LAKE SALINE COMPARED WITH THOSE IN LAKE MICHIGAN SEDIMENTS

John C. Frye and Neil F. Shimp

INTRODUCTION

During the past few years intensive studies have been made of the trace and major elements in the bottom sediments of southern Lake Michigan (Shimp, Leland, and White, 1970; Ruch, Kennedy, and Shimp, 1970; Schleicher and Kuhn, 1970; Shimp et al., 1971; and Kennedy, Ruch, and Shimp, 1971). A major objective of these studies has been to determine the natural, pre-industrial, background concentrations of trace elements and the increase in such elements in the uppermost layer of sediments deposited since cities developed on and near the lake shore.

Because the earth is a dynamically changing system, meaningful background, or "natural," conditions are very difficult to determine. In southern Lake Michigan, the age of the glacial till that underlies the lacustrine sediments of the present lake is probably only slightly more than 13,000 radiocarbon years before present. In addition, the lacustrine sediments analyzed were not sampled to their contact with the underlying till. The oldest chemical record from Lake Michigan sediments, therefore, is somewhat less than 13,000 years old. Furthermore, as Lake Michigan sediments are only slightly compacted and are locally thin, at least a slight possibility exists that some pollutants have penetrated into the sediments below the surface layer, with a resultant distortion of what have been considered background determinations.

One possible approach to obtaining additional data on chemical background extending into Pleistocene time is to study deposits of a glacially fed lake that existed beyond the limit of Wisconsinan glaciers and received sediments during the times that glaciers occupied the basin of Lake Michigan. One such lake, now called Lake Saline, once existed in south-

eastern Illinois during the Wisconsin Stage, and its history and deposits have recently been studied (Frye et al., 1972).

The Lake Saline deposits are particularly suitable for extending the chemical background because (1) the water and sediments of the lake came from the glacial lobes to the north and northeast, (2) the sediments are predominantly clay and silt and therefore can be studied by the same techniques used for Lake Michigan bottom sediments, (3) the sediments have been dated by radiocarbon methods and stratigraphic correlation, and (4) the youngest deposits of Lake Saline have been dated at 13,000 radiocarbon years B.P. (ISGS-103), which is virtually the same age attributed to the oldest bottom sediments in southern Lake Michigan. Because glaciers not only occupied the basin of Lake Michigan but also extended far beyond its limits at the time Lake Saline sediment was accumulating, the source of sediment is not identical for the two lakes. However, the glacially derived sediments that fed Lake Saline came from the same general region as those deposited later in Lake Michigan, or from the region to the northeast.

From the many samples collected and analyzed for clay minerals during the study of Lake Saline deposits, 22 were selected for chemical analysis of trace and major elements. The samples cover the span of time from 13,000 radiocarbon years B.P. to 35,000 or more radiocarbon years B.P., which is in the Altonian Substage. Several other samples were selected, some from the younger deposits formed by weathering of the lake deposits and some from deposits on the lake plain that were produced by wash from the adjacent slopes and are called overwash deposits. The analytical data not only furnish background information for trace element evaluation in pollution studies but also provide a basis for comparing the Lake Saline deposits with weathered materials.

Chemical analyses were made by the Analytical Chemistry Section of the Illinois State Geological Survey; the methods employed were those described in Shimp, Leland, and White, 1970; Ruch, Kennedy, and Shimp, 1971; and Kennedy, Ruch, and Shimp, 1971. Clay mineral analyses were made by H. D. Glass for Illinois State Geological Survey Circular 471 (Frye et al., 1972). Radiocarbon dates were determined by D. D. Coleman. The stratigraphy of southern Lake Michigan bottom sediments and core descriptions were given in Gross et al., 1970; Lineback, Ayer, and Gross, 1970; Lineback et al., 1971; Lineback, Gross, and Meyer, 1972; Gross et al., 1972; and Lineback and Gross, 1972.

LAKE SALINE

The former Lake Saline existed intermittently during the Wisconsin Stage of the Pleistocene Epoch in southeastern Illinois, largely in Gallatin and Saline Counties. As the location, history, and deposits of the lake have recently been described in detail in Circular 471 (Frye et al., 1972), descriptions will not be repeated here. Circular 471 contains a map of the lake; tables giving location, clay mineral analyses, radiocarbon dates, and textural analyses of all samples; descriptions of stratigraphic sections; and a list of the molluscan fossils found and their paleoecological implications. All sample numbers noted here that are preceded by "P-" are fully described in the Circular.

In the basin of Lake Saline the southern limit of Illinoian glaciation was reached, but the sediments with which we are concerned here are of Wisconsinan and Holocene ages. The lake basin is slightly more than 100 miles south of the southern limit of Wisconsinan glaciers in Illinois and was fed by glacial waters carrying outwash from the north via the Wabash River, and from the northeast by way of the Ohio River. The lake was an impoundment in pre-Wisconsinan tributary valleys and occurred back of "dams" of outwash deposits that partly filled both the Wabash and Ohio River valleys.

When the ice retreated during the Farmdalian Substage, the lake level receded, leaving some of the lake deposits exposed to weathering and erosion, but when the extensive glacial advances during the Woodfordian Substage took place, lake levels rose to their highest position and lake sediments spread extensively over the earlier lake plain. All the lake deposits are classified within the Equality Formation (Willman and Frye, 1970), but as the time sequence is of primary concern here, they will be referred to by the name of the time-stratigraphic unit in which they belong.

CHEMICAL COMPOSITION OF LAKE SALINE DEPOSITS

Results of analyses for major and minor constituents of the samples from Lake Saline are given in table 1 and data for trace elements in table 2. Mean values and concentration ranges for the stratigraphic units are given in table 3. The most significant constituents present in the samples are shown in figures 1 and 2. The graph in figure 1 is plotted to show selected analytical data arranged in stratigraphic sequence; it combines samples from four adjacent Lake Saline stratigraphic sections described in Circular 471. The bottom sample (P-7402) is from the Horseshoe Section; the next five samples alternate between the Ridgeway West and Equality NE Sections; the next three samples are from the Equality NE Section; and the top two are from the Cypress Ditch Auger Sections.

The major elements, expressed as oxides (CaO , CO_2 , MgO), and loss on ignition reflect the general stratigraphy in that their percentages are all quite low in the weathered zone of the Farmdale Soil and are at intermediate levels in the top sample, which has been somewhat affected by weathering of the Modern Soil. The percentage of illite in the clay minerals shows the same general relation but in exaggerated form. The silica percentage is the reverse of these values because quartz and the silicates are the least weatherable of the minerals; therefore, the silica percentage of the total increases as the carbonate minerals are removed.

Of the trace elements, only boron shows a consistent pattern. The amount roughly, but not perfectly, follows the curve for illite, indicating that it largely occurs associated with that clay mineral. The zinc concentration fluctuates but has no readily apparent correlation with other chemical or mineral components or with the stratigraphy. With the exception of arsenic, which is anomalously high in samples P-7304, P-7386, P-7442, and P-7447, the trace elements in the Lake Saline deposits occur in relatively low concentrations, have only minor variations, and appear to reflect a natural background distribution.

TABLE 1—CHEMICAL COMPOSITION OF LAKE SALINE SEDIMENTS: MAJOR AND MINOR CONSTITUENTS*

Sample	Oven-dry (110° C) weight in percent															Total	
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Fe ₂ O ₃	Na ₂ O	P ₂ O ₅	H ₂ O [†] (110° C)	CO ₂	S	Ignition loss [‡]	Organic carbon		< 2-micron clay
P-7299	61.1	1.06	17.60	7.09	0.14	0.70	0.75	3.41	0.72	0.83	4.73	1.28	0.01	6.33	0.31	--	99.73
P-7301	82.9	0.96	7.37	1.65	0.03	0.43	0.50	1.69	0.59	0.63	2.37	0.02	0.01	2.78	0.38	--	99.53
P-7304	66.2	0.74	8.15	3.31	0.01	1.08	2.74	2.04	1.12	0.82	5.92	1.32	0.04	13.78	6.14	37*	99.99
P-7305	54.2	0.68	10.90	4.96	0.05	4.46	7.95	3.07	0.65	1.00	3.22	8.21	0.09	12.44	0.92	42	99.66
P-7307	51.2	0.57	7.56	3.28	0.05	5.41	11.80	2.67	0.75	0.44	2.60	13.16	0.01	15.96	0.19	--	99.67
P-7359	41.6	0.53	6.82	2.87	0.09	7.19	16.50	2.20	0.92	1.36	1.88	17.70	0.01	19.72	0.13	--	99.74
P-7367	48.3	0.56	10.40	3.49	0.06	4.82	12.50	2.81	0.79	0.51	2.37	12.68	0.01	15.32	0.26	52*	99.58
P-7360	41.6	0.53	10.91	4.74	0.06	5.66	14.08	3.27	0.72	0.27	2.87	14.72	0.02	17.81	0.02	--	99.65
P-7386	58.8	0.65	11.90	8.02	0.15	2.45	4.59	2.78	0.77	0.74	3.67	4.46	0.01	8.67	0.53	53*	99.52
P-7373	76.0	0.74	10.80	6.66	0.14	0.93	0.36	1.96	0.66	0.06	3.45	0.17	0.01	3.96	0.33	29	99.62
P-7402	41.1	0.51	10.80	4.81	0.06	6.39	13.2	3.39	0.61	0.58	2.93	14.81	< 0.01	18.09	0.34	54	99.54
P-7442	49.2	0.74	13.3	7.20	0.09	3.60	8.51	3.37	0.45	0.32	3.83	8.57	0.02	12.66	0.24	58	99.44
P-7448	74.7	1.02	13.0	2.65	0.02	0.46	0.89	1.88	0.81	0.54	3.36	0.42	0.01	3.93	0.14	48	99.80
P-7451	50.6	0.60	9.55	3.35	ND	4.30	11.65	2.73	0.67	0.50	2.52	12.68	0.01	15.44	0.23	45*	99.44
P-7456	61.6	0.43	7.92	3.25	0.02	0.96	10.60	1.95	0.79	0.40	9.81	8.67	0.10	12.32	1.04	28	99.74
P-7460	80.5	0.35	8.75	1.60	0.02	0.54	1.01	2.08	0.91	0.47	1.22	0.05	< 0.01	1.61	0.33	45*	99.84
P-7467	73.2	0.58	10.4	4.85	0.10	0.60	1.76	2.17	0.98	0.54	2.74	1.09	0.03	4.95	0.73	26	99.72
P-7477	56.7	0.48	10.6	8.91	0.25	1.61	5.20	2.05	0.71	0.99	5.03	3.92	0.06	12.13	3.12	--	99.63
P-7481	71.3	0.82	14.0	4.77	0.07	0.67	0.70	2.67	1.12	0.26	3.05	0.37	0.01	3.53	0.01	--	99.91
P-7482	73.0	0.81	11.1	5.16	0.08	1.08	0.65	2.75	1.10	0.28	3.58	0.19	0.01	4.03	0.25	43	100.04
P-7488	80.7	0.83	8.55	3.25	0.05	0.03	0.18	2.04	1.13	0.16	2.81	0.29	< 0.01	3.20	0.09	--	100.12
P-7484	76.0	0.83	10.4	5.29	0.09	0.05	0.43	2.10	1.06	0.21	3.07	0.10	< 0.01	3.44	0.26	--	99.90

* Analyses by L. R. Camp, W. F. Harfst, D. B. Heck, and J. K. Kuhn.

† H₂O = ignition loss — (organic carbon + CO₂ + S).

‡ Not included in totals.

* Value of near-by similar sample used.

ND No data.

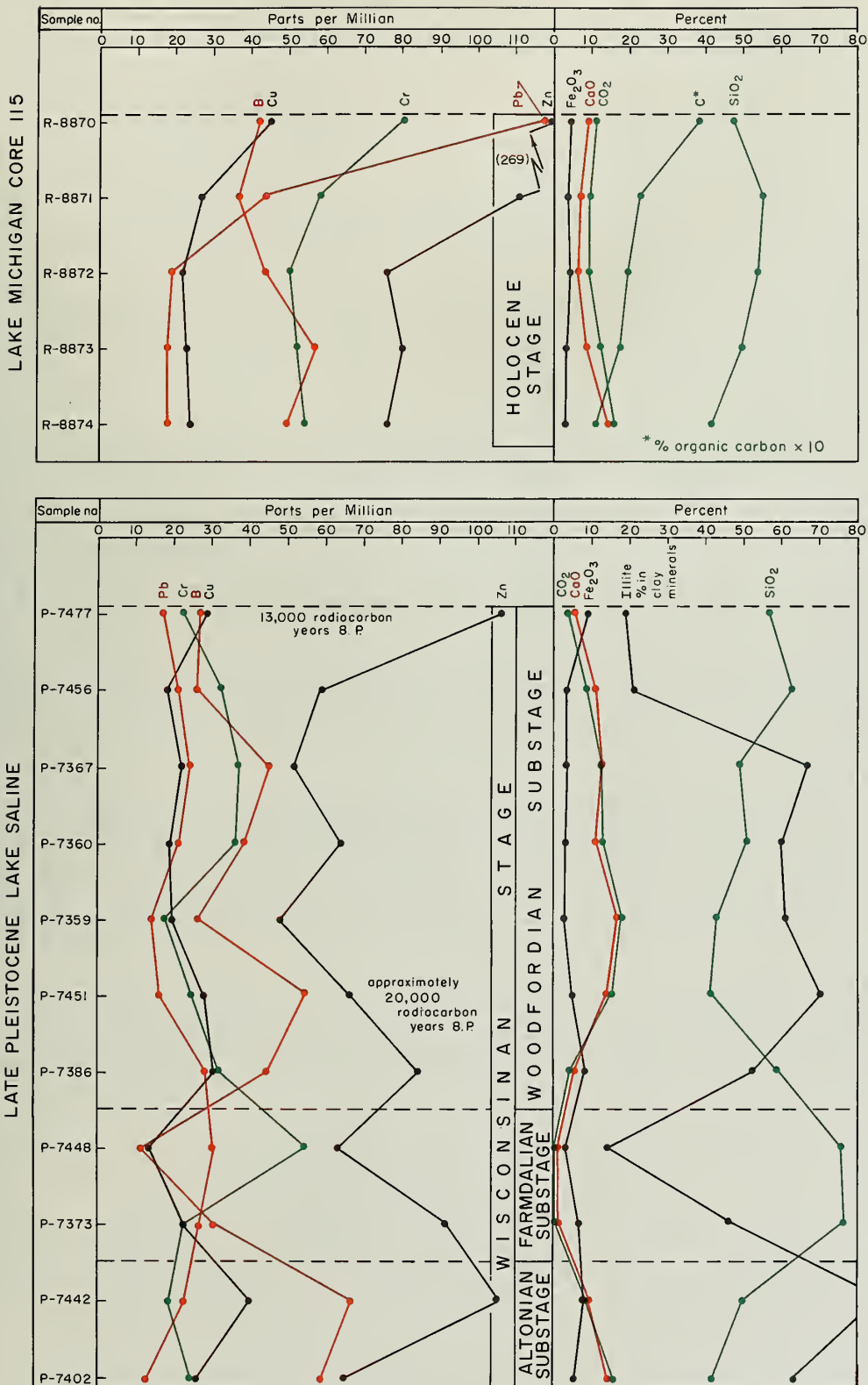


Fig. 1 - Chemical composition of samples from Lake Michigan core 115 and from a composite stratigraphic sequence of deposits in Wisconsin Lake Saline. Location and description of samples with the prefix R- were given in Shimp et al. (1971) and of samples with the prefix P- in Frye et al. (1972). The number (269) is the zinc concentration for the sample R-8870 extended off scale.

TABLE 2—CHEMICAL COMPOSITION OF LAKE SALINE SEDIMENTS: TRACE ELEMENTS*

Sample	Air-dry weight in parts per million													
	Br	La	Sc	Co	Hg	As	Pb	Zn	Cu	Ni	B	Be	Cr	V
P-7299	< 12	57	29	13	0.24	4	30	65	32	19	33	4.7	34	38
P-7301	< 21	39	33	8	0.06	2	16	115	13	19	10	1.9	24	28
P-7304	< 35	36	9	11	0.07	26	12	62	32	22	18	2.0	17	28
P-7305	< 20	38	11	15	0.05	9	12	73	24	10	48	2.0	14	18
P-7307	< 17	26	8	11	0.04	8	18	54	20	26	37	2.2	21	44
P-7359	< 11	26	8	11	0.05	4	14	48	19	22	27	1.2	18	26
P-7367	< 16	29	9	12	0.05	4	24	57	22	27	45	3.0	37	54
P-7360	< 14	29	10	15	0.06	5	16	66	28	20	54	1.2	25	29
P-7386	< 25	49	11	29	0.08	18	28	84	30	24	44	4.2	31	46
P-7373	< 33	37	10	21	0.09	16	26	91	22	30	30	3.0	22	31
P-7402	< 16	34	10	13	0.07	8	12	64	25	18	58	1.4	24	20
P-7442	< 36	34	13	16	0.07	25	22	105	39	27	66	3.1	18	36
P-7448	< 11	41	11	8	0.06	4	30	63	13	19	11	3.7	54	60
P-7451	< 13	28	8	11	0.04	8	20	64	19	14	38	3.6	36	23
P-7456	< 17	23	5	8	0.20	9	21	59	18	26	26	4.3	32	63
P-7460	< 11	27	8	13	0.03	4	20	53	11	15	17	1.8	24	33
P-7467	< 20	27	8	13	0.06	13	24	76	21	15	18	2.8	33	34
P-7477	< 36	30	9	5	0.06	29	17	106	28	22	27	2.3	22	31
P-7481	--	39	11	13	0.08	9	20	81	22	18	23	2.8	24	28
P-7482	< 12	37	11	14	0.08	8	22	95	22	30	28	2.2	32	48
P-7488	< 17	39	8	16	0.16	7	24	49	16	21	13	2.4	22	30
P-7484	< 21	35	9	14	0.13	16	26	80	25	31	16	2.6	30	24

*Analyses by D. B. Heck, L. R. Henderson, J. K. Frost, R. R. Ruch, and J. A. Schleicher.

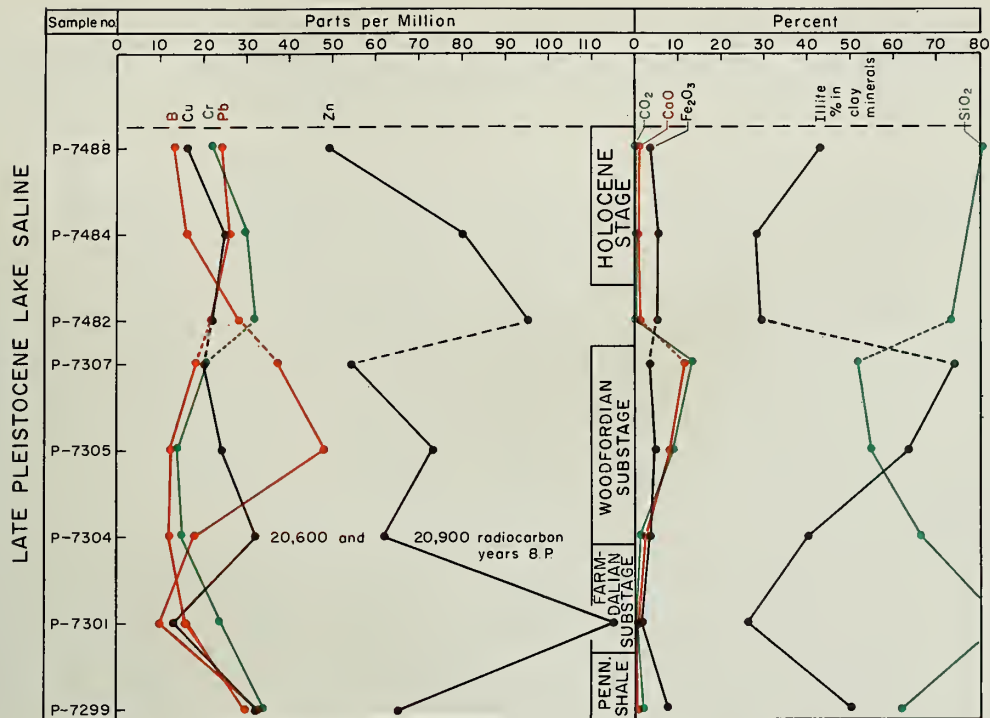


Fig. 2 - Chemical composition of samples of weathered post-Lake Saline deposits occurring in the area of the former lake and of samples of lake deposits and underlying weathered shale at the Big Ridge Section. Location and description of samples and of the stratigraphic sequence were given by Frye et al. (1972).

In figure 2 the same constituents have been plotted for the Big Ridge Section, for the young, weathered overwash deposits, and for weathered lake sediments. The stratigraphic relations shown here are the same as those described for the composite sequence presented in figure 1, and the young, weathered deposits resemble in most respects the Farmdale Soil that occurs within the sequence of lake beds.

The sample shown at the bottom of figure 2 is weathered Pennsylvanian shale, which lies immediately below the Wisconsinan deposits. Even in this sample the trace element content does not differ markedly from that of the Pleistocene lake beds.

CHEMICAL COMPOSITION OF LAKE MICHIGAN AND PEORIA LAKE BOTTOM SEDIMENTS

Mean concentrations for major, minor, and trace constituents in the top intervals (0-10 cm) and in the 16 to 100 cm sediment intervals for southern Lake Michigan cores are given in table 3. The chemical composition of a typical southeastern Lake Michigan core, which exhibits accumulations of arsenic, bromine, chromium, copper, mercury, lead, zinc, and organic carbon in the uppermost portions of the sediment, is shown in table 4, and selected constituents are graphically plotted in figure 1. Comparable accumulations of trace elements occur in many of the younger fine-grained surficial sediments

TABLE 3—MEAN AND RANGE OF MAJOR, MINOR, AND TRACE ELEMENT CONCENTRATIONS IN SEDIMENTS FROM PEORIA LAKE, LAKE MICHIGAN, AND LAKE SALINE ¹

Sediment Source	Air-dry weight in parts per million											
	As	B	Be	Br	Co	Cr	Cu	Hg	Ni	Pb	V	Zn
Peoria Lake*	12 5-13 (15)	36 10-52 (15)	2.7 1.8-4.0 (15)	‡ < 20 (15)	12 6-17 (15)	151 64-261 (15)	62 22-88 (15)	0.23 0.12-0.39 (15)	54 18-77 (15)	145 52-204 (15)	78 22-113 (15)	446 185-667 (15)
Lake Michigan†: Top interval‡ (0 to 10 cm)	14 8-30 (15)	41 14-71 (21)	1.8 0.6-3.0 (24)	62# < 20-132 (20)	13 7-24 (22)	77 35-165 (24)	37 9-75 (22)	0.20 0.06-0.38 (21)	34 18-58 (24)	88 27-172 (24)	48 7-83 (24)	206 58-519 (22)
Lake Michigan†: All intervals > 15 cm but < 100 cm	5 2-8 (24)	48 17-71 (24)	1.7 0.7-3.2 (23)	35# < 20-72 (19)	14 6-22 (23)	52 32-68 (24)	20 8-29 (24)	0.05 0.04-0.08 (28)	35 12-54 (23)	20 16-48 (23)	62 26-99 (23)	66 22-129 (23)
Lake Saline: Overwash and slack- water deposits. Cottage Grove and Equality Old Bridge	10 7-16 (4)	20 13-28 (4)	2.5 2.2-2.8 (4)	‡ < 20 (4)	14 13-16 (4)	27 22-32 (4)	21 16-25 (4)	0.11 0.08-0.16 (4)	25 18-31 (4)	23 20-26 (4)	32 24-48 (4)	76 49-95 (4)
Lake Saline: Altonian and Woodfordian	13 2-29 (12)	41 18-66 (12)	2.5 1.2-4.3 (12)	‡ < 20 (12)	13 5-29 (12)	24 14-37 (12)	25 18-39 (12)	0.07 0.04-0.20 (12)	22 10-27 (12)	18 12-28 (12)	35 18-63 (12)	70 48-106 (12)
Lake Saline: Farmdalian	7 2-16 (3)	17 10-30 (3)	2.9 1.9-3.7 (3)	‡ < 20 (3)	12 8-21 (3)	33 22-54 (3)	16 13-22 (3)	0.07 0.06-0.09 (3)	23 19-30 (3)	24 16-30 (3)	40 28-60 (3)	89 63-115 (3)
	Oven-dry (110° C) weight in percent											
	MnO	P ₂ O ₅	Organic carbon	SiO ₂	Fe ₂ O ₃	CaO	CO ₂	Ignition loss	< 2-micron clay			
Peoria Lake*	0.084 0.046-0.113 (15)	0.69 0.18-1.22 (15)	2.54 0.71-3.49 (15)	59.8 56.1-69.0 (15)	4.81 2.61-5.77 (15)	4.91 3.70-7.49 (15)	4.90 3.52-7.66 (15)	12.36 9.78-14.93 (15)	-- 12-31 (15)			
Lake Michigan†: Top interval‡ (0 to 10 cm)	0.072 0.025-0.212 (25)	0.15# < 0.01-0.42 (56)	2.51≈ 0.77-4.73 (25)	53.1 ^X 40.2-70.2 (24)	4.04 ^X 2.09-9.99 (24)	7.83 ^X 4.37-15.90 (24)	10.81 ^X 5.16-20.69 (24)	16.10 ^X 9.15-20.33 (24)	30≈ 10-69 (25)			
Lake Michigan†: All intervals > 15 cm but < 100 cm	0.050 0.027-0.110 (24)	0.17## < 0.01-0.46 (73)	1.40≈ 0.49-2.65 (23)	48.4 ^X 41.5-58.9 (31)	3.56 ^X 1.74-5.99 (31)	9.14 ^X 3.37-15.00 (32)	11.57 ^X 3.17-19.36 (32)	17.46 ^X 11.09-20.91 (32)	40≈ 11-65 (24)			
Lake Saline: Overwash and slack- water deposits. Cottage Grove and Equality Old Bridge	0.072 0.070-0.090 (4)	0.23 0.16-0.28 (4)	0.12 0.09-0.26 (4)	75.25 71.3-80.7 (4)	4.61 3.25-5.29 (4)	0.49 0.18-0.70 (4)	0.24 0.10-0.37 (4)	3.55 3.20-4.03 (4)	-- -- (4)			
Lake Saline: Altonian and Woodfordian	0.060# ‡ -0.150 (12)	0.66 0.27-1.36 (12)	0.10 0.02-6.14 (12)	51.8 41.4-66.2 (12)	4.79 2.87-8.91 (12)	9.94 2.74-16.50 (12)	10.07 1.32-17.70 (12)	14.52 8.67-19.72 (12)	~ 45 25-60 (10)			
Lake Saline: Farmdalian	0.060 0.020-0.140 (3)	0.41 0.06-0.63 (3)	0.26 0.14-0.33 (3)	77.9 74.7-82.9 (3)	3.65 1.65-6.66 (3)	0.58 0.36-0.89 (3)	0.20 0.02-0.42 (3)	3.56 2.78-3.96 (3)	-- -- (3)			

¹ Values in parentheses = number of determinations used for calculating the mean.

* Data from Collinson and Shimp, 1972.

† Data from Shimp, Leland, and White, 1970; Ruch, Kennedy, and Shimp, 1970; Schleicher and Kuhn, 1970; Shimp et al., 1971; and Kennedy, Ruch, and Shimp, 1971.

‡ Top interval sediments selected to contain ≥ 0.75% organic carbon and ≥ 10% less than 2-micron clay-size material.

Not detected.

‡ "Less-than" values are not included in the mean.

‡ Greater than 10.5 cm interval.

≈ Data from Shimp et al., 1971.

^X Unpublished calculated means. A forthcoming EON will compile the data on major elements in Lake Michigan sediments.

of southeastern and south-central Lake Michigan (Shimp, Leland, and White, 1970; Ruch, Kennedy, and Shimp, 1970; Shimp et al., 1971; and Kennedy, Ruch, and Shimp, 1971). A close correlation between organic carbon and the aforementioned trace elements also was established.

Previous work (Shimp et al., 1971; Lineback and Gross, 1972) showed that the youngest, or uppermost, Lake Michigan sediments vary significantly in both physical and chemical characteristics. To obtain a group of similar Lake Michigan sediments, only the arithmetic means of those samples that contained at least 0.75 percent organic carbon and 10 percent clay-size material were included in table 3. Nevertheless, variations in the trace element concentrations of this group of Lake Michigan sediments still persisted, and many of the trace elements in the top interval samples (table 3) exhibit rather wide concentration ranges. The samples selected for comparison are different from those used by Lineback and Gross (1972) because the purpose here was to average data from Lake Michigan samples that possessed textures similar to those from Lake Saline; Lineback and Gross (1972) wanted to show regional differences in the uppermost sediments of southern Lake Michigan. Fortunately, for this study the 0 to 10 cm sediment values do not require precise interpretation and are included primarily to illustrate the general order of magnitude of trace element accumulation in the younger Lake Michigan sediments. Pollution studies will require more exact estimates, made on a local rather than a regional basis.

In the underlying 15 to 100 cm interval of southern Lake Michigan sediments, trace element ranges tend to be much narrower than in the 0 to 10 cm interval. This is especially true of bromine, chromium, copper, mercury, lead, and zinc, which are the elements known to be accumulating in the 0 to 10 cm interval of central and southeastern Lake Michigan sediments and for which natural background concentrations are of most concern. The "nonaccumulating" trace elements, boron, beryllium, cobalt, nickel, and vanadium, show little concentration variation throughout the 0 to 100 cm sediment depth in the Lake Michigan sequence.

In contrast to the trace element concentrations, which decrease with sediment depth, average concentrations of major elements in southeastern Lake Michigan sediments are relatively constant to a sediment depth of about 100 cm (see table 3 and fig. 1).

The mean chemical composition of 15 Peoria Lake sediment samples is also included in table 3. Complete descriptions and analyses for these sediment samples were published by Collinson and Shimp (1972). Peoria Lake, which has for decades received wastes from municipal and industrial areas along its banks, is a 13-mile long impoundment of the slow-moving Illinois River near Peoria. It has special significance for the ecology, siltation, and pollution levels in the Illinois River.

COMPARISONS AND CONCLUSIONS

Shimp et al. (1971) suggested that a portion of the accumulation of trace elements in the younger bottom sediments of southern Lake Michigan results

TABLE 4—MAJOR, MINOR, AND TRACE ELEMENT CONTENTS OF LAKE MICHIGAN CORE 115*

Constituent	Depth interval (cm)				
	0 - 3	3 - 6	6 - 9	38 - 44	98 - 103
Major and Minor Constituents (%)					
SiO ₂	47.6	54.3	53.6	49.4	41.8
TiO ₂	0.51	0.56	0.51	0.52	0.48
Al ₂ O ₃	9.42	8.72	10.00	9.92	10.40
Fe ₂ O ₃	4.24	3.83	4.19	3.23	2.99
MnO	0.072	0.106	0.096	0.083	0.066
MgO	5.58	5.88	5.49	6.77	5.35
CaO	9.36	7.21	6.34	8.35	15.10
Na ₂ O	0.61	0.69	0.73	0.62	0.54
K ₂ O	2.41	2.57	2.86	2.77	2.62
P ₂ O ₅	0.34	0.59	0.60	0.46	0.35
H ₂ O†	4.03	3.09	3.88	2.98	2.76
CO ₂	11.30	9.57	8.71	11.98	15.86
S	0.07	0.04	0.03	0.08	0.07
Ignition loss†	19.21	14.95	14.04	16.77	19.82
Organic C	3.81	2.25	1.92	1.73	1.13
Clay‡	<u>48</u>	<u>30</u>	<u>45</u>	<u>44</u>	<u>48</u>
Total	99.97	100.05	98.46	98.99	98.52
Trace Elements (ppm)					
As	15	9	8	4	--
B	42	37	44	57	50
Be	1.9	1.8	1.8	1.8	1.7
Br	90	60	47	33	18
Co	15	12	12	14	12
Cr	80	58	50	52	54
Cu	45	27	22	23	24
Hg	0.24	0.09	0.05	0.04	0.05
La	24	23	28	28	25
Ni	40	34	36	40	30
Pb	125	44	19	18	18
Sc	10	9	9	10	9
V	66	66	68	73	61
Zn	269	111	76	80	76

*Core location: 15 miles west of Benton Harbor, Michigan, 31°00' lat., 86°43.79' long.; water depth 230 feet.

† H₂O = ignition loss — (organic carbon + CO₂ + S).

‡ Not included in total.

TABLE 5—FIRST APPROXIMATION OF TRACE AND MINOR ELEMENT BASE LINE RANGES FOR SOUTHERN LAKE MICHIGAN BOTTOM SEDIMENTS*

Element (ppm)	Base line	Element (ppm)	Base line
As	< 8 [†]	Hg	0.05-0.10
B	30-50	Ni	15-40
Be	1-2	Pb	15-30
Br	< 40	V	30-60
Co	10-20	Zn	50-100
Cr	20-40	MnO (%)	0.05-0.10
Cu	15-30	P ₂ O ₅ (%)	< 0.3 [†]

* Fine-grained bottom sediments only.

† Estimated from the 15 to 100 cm Lake Michigan sediment intervals only.

from pollution caused by man's activities in the surrounding watershed. Previously, no attempt had been made to distinguish between pollutants added to the sediments by man's activities and those that are contributed by natural processes. We believe that comparison of the chemical data from Lakes Saline, Michigan, and Peoria permits a first approximation to be made of the quantity of trace elements derived from each of these two sources. Data from Shimp et al. (1971) and Lineback and Gross (1972) indicated that trace element accumulation in southern Lake Michigan bottom sediments seems to be closely related to sediment discharge from southeastern Michigan rivers—the Grand, Kalamazoo, and St. Joseph. However, none of the data permits evaluation of relative contributions from air, stream, and runoff sources.

The average concentrations of major elements, organic carbon, and clay-size material (table 3) in Lake Saline (Altonian and Woodfordian) are very similar to those of Lake Michigan sediments (top and 15 to 100 cm intervals). In contrast, the more weathered Lake Saline deposits (overwash) and Farmdale Soil are depleted in carbonates. These chemical data strongly support the original stratigraphic interpretations made by Frye et al. (1972). Despite the excellent relation between major elements and stratigraphic units in the Lake Saline sequence, no such correlation is evident for the trace elements. Apparently, weathering of the Pleistocene deposits had little effect upon trace element concentrations. Therefore, trace elements cannot be used as indicators for the Lake Saline sediments in stratigraphic interpretations.

Further examination of table 3 and figure 1 discloses that mean trace element concentrations of all Pleistocene Lake Saline sediments are very similar to those of Lake Michigan sediments in the 15 to 100 cm interval. Such a favorable comparison, especially for the Woodfordian and Altonian deposits, tends to support the conclusion that trace element base line values for the uppermost layer of Lake Michigan sediments can be estimated from

analyses of the underlying lake sediments. A first approximation of base line ranges for each trace element has been made from the mean values given in table 3. These are shown in table 5. The 15 to 100 cm Lake Michigan and Lake Saline (Woodfordian and Altonian) samples were used to approximate base line concentration ranges for all trace elements except arsenic and phosphorus. Because the phosphorus concentrations in Lake Saline deposits are higher than those in the youngest sediments from southern Lake Michigan and because several of the Lake Saline samples are anomalously high in arsenic, only the 15 to 100 cm Lake Michigan intervals were used for the arsenic and phosphorus base line approximations.

The mean trace element concentrations for Peoria Lake sediments given in table 3 indicate polluted sediments similar in major element and clay composition to Lake Michigan sediments. In general, trace element concentrations for Peoria Lake sediments are comparable to, or somewhat higher than, those found in the uppermost layer of the fine-grained sediments in southeastern Lake Michigan (Collinson and Shimp, 1972).

Although organic carbon concentrations as high as 6 percent were observed in glacial Lake Saline sediments, no consistent correlation of trace elements with organic carbon similar to that found in the top (0-10 cm) sediments of southern Lake Michigan was observed. Therefore, the relation between trace elements and organic carbon in Lake Michigan sediments appears to be a recent phenomenon associated with man's activities.

Two instances of high arsenic concentration (P-7304 and P-7477) in Lake Saline sediments may be associated with high organic matter content. However, other Lake Saline sediments (P-7386 and P-7442 for example), contain anomalously high arsenic concentrations but very low organic carbon levels. High arsenic values for the deeper portions of several Lake Michigan cores have been associated with pyritic inclusions (Ruch, Kennedy, and Shimp, 1970).

In conclusion, comparison of the chemical composition of Lake Saline sediments with that of Lake Michigan sediments demonstrates that base line concentrations of trace elements for the most recently deposited southern Lake Michigan sediments may be estimated from trace element determinations made on the older underlying sediments. Furthermore, the analysis of Lake Saline deposits proves that accumulations of trace elements, similar to those found in the uppermost layer of many southern Lake Michigan sediments, did not occur in glacial Lake Saline deposits.

The theory that significant additions of trace elements are being made to southern Lake Michigan bottom sediments as a direct result of man's activities in the surrounding watershed is strongly reinforced by this study.

REFERENCES

- Collinson, Charles, and N. F. Shimp, 1972, Trace elements in bottom sediments from Upper Peoria Lake, Middle Illinois River—A pilot project: Illinois Geol. Survey Environmental Geology Note 56, 21 p.
- Frye, J. C., A. B. Leonard, H. B. Willman, and H. D. Glass, 1972, Geology and paleontology of late Pleistocene Lake Saline, southeastern Illinois: Illinois Geol. Survey Circ. 471, 44 p.
- Gross, D. L., J. A. Lineback, W. A. White, N. J. Ayer, Charles Collinson, and H. V. Leland, 1970, Preliminary stratigraphy of unconsolidated sediments from the southwestern part of Lake Michigan: Illinois Geol. Survey Environmental Geology Note 30, 20 p.
- Gross, D. L., J. A. Lineback, N. F. Shimp, and W. A. White, 1972, Composition of Pleistocene sediments in southern Lake Michigan, U.S.A.: 24th Internat. Cong. Proc., Sec. 8, Montreal, p. 215-222.
- Kennedy, E. J., R. R. Ruch, and N. F. Shimp, 1971, Distribution of mercury in unconsolidated sediments from southern Lake Michigan: Illinois Geol. Survey Environmental Geology Note 44, 18 p.
- Lineback, J. A., N. J. Ayer, and D. L. Gross, 1970, Stratigraphy of unconsolidated sediments in the southern part of Lake Michigan: Illinois Geol. Survey Environmental Geology Note 35, 35 p.
- Lineback, J. A., and D. L. Gross, 1972, Depositional patterns, facies, and trace element accumulation in the Waukegan Member of the late Pleistocene Lake Michigan Formation in southern Lake Michigan: Illinois Geol. Survey Environmental Geology Note 58, 25 p.
- Lineback, J. A., D. L. Gross, and R. P. Meyer, 1972, Geologic cross sections derived from seismic profiles and sediment cores from southern Lake Michigan: Illinois Geol. Survey Environmental Geology Note 54, 43 p.
- Lineback, J. A., D. L. Gross, R. P. Meyer, and W. L. Unger, 1971, High-resolution seismic profiles and gravity cores of sediments in southern Lake Michigan: Illinois Geol. Survey Environmental Geology Note 47, 41 p.
- Ruch, R. R., E. J. Kennedy, and N. F. Shimp, 1970, Distribution of arsenic in unconsolidated sediments from southern Lake Michigan: Illinois Geol. Survey Environmental Geology Note 37, 16 p.
- Schleicher, J. A., and J. K. Kuhn, 1970, Phosphorus content of unconsolidated sediments from southern Lake Michigan: Illinois Geol. Survey Environmental Geology Note 39, 15 p.
- Shimp, N. F., H. V. Leland, and W. A. White, 1970, Distribution of major, minor, and trace constituents in unconsolidated sediments from southern Lake Michigan: Illinois Geol. Survey Environmental Geology Note 32, 19 p.

Shimp, N. F., J. A. Schleicher, R. R. Ruch, D. B. Heck, and H. V. Leland, 1971, Trace element and organic carbon accumulation in the most recent sediments of southern Lake Michigan: Illinois Geol. Survey Environmental Geology Note 41, 25 p.

Willman, H. B., and J. C. Frye, 1970, Pleistocene stratigraphy of Illinois: Illinois Geol. Survey Bull. 94, 204 p.

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